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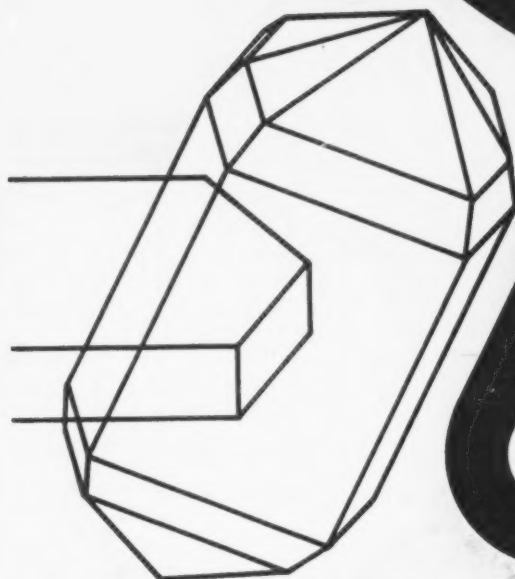
ABSTRACT

There are many reasons for studying Antarctica. It is the key element in the world's climate. Some of the secrets of the earth's past are locked beneath its icecap. It has a fascinating physical environment and a unique and fragile ecosystem. It is a frontier of scientific research and technological development. Its history is an important and dramatic story of discovery and exploration. These materials were developed to be used by children so that they will understand the problems and importance of Antarctica. Topics include heat flow, optical phenomena, windchill, atmospheric pressure, magnetism, electric charge, friction, chemical reactions, and moving ice. (KR)

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What Happened in Antarctica

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IT HAPPENED IN ANTARCTICA

A collection of observations
requiring scientific explanations

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Development
Centre
Canberra
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The Author

Murray Yaxley holds a Bachelor of Science from the University of Tasmania and a Bachelor of Education from the University of Melbourne. He taught in many Tasmanian high schools and in 1952 he helped form the Science Teachers Association of Tasmania. Murray has travelled widely in Europe, Asia, North America and Africa, studying developments in science education and as an educational consultant. He worked as project officer of the Antarctic Project over the period 1981-85, and is the author of many titles in this series.

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Why study Antarctica?

For the teacher

One of the aims of the Pacific Circle Consortium is the development of educational materials with an international perspective, particularly materials that take into account the half of the earth's surface covered by the Pacific Ocean. To the south of the Pacific lie the Southern Ocean and the great Antarctic continent.

There are many reasons for studying Antarctica. It is the key element in the world's climate. Some of the secrets of the earth's past are locked beneath its icecap. It has a fascinating physical environment and a unique and fragile ecosystem. It is a frontier of scientific research and technological development.

Antarctica is unique and its history is an important and dramatic story of discovery and exploration. This story is sometimes inspiring, sometimes tragic, but it has much to teach us about how people react under extreme conditions and how they can live with each other and their environment.

The Pacific Circle Consortium believes that educational materials are most valuable when developed jointly, reflecting interests, issues and concerns that extend beyond national boundaries. For New Zealand and Australia, Antarctica is the Near South. Both New Zealand and Australia, along with other Pacific Circle members, Japan and the United States, are original signatories to the Antarctic Treaty. In that treaty, the nations

recognised that it was in the interests of all the human race that Antarctica should forever be used only for peaceful purposes, that freedom and international cooperation in scientific work in Antarctica would contribute to science and the progress of the human race.

The conservation and protection of the relatively pristine Antarctic environment is vital to our two nations. The wise international use and management of Antarctic resources will present many challenges that we, with the rest of the world community, will have to face and overcome.

For our own sakes and for the sake of the future of the whole world, the children of the Pacific must understand Antarctica, its problems and its importance.

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Introduction

The weather and seasonal conditions in Antarctica are unique. Antarctica is not only a land of extremes, but also can be a land of contrasts. For example, you will read of whiteouts. People caught in whiteouts cannot go anywhere. They become disoriented and cannot judge distances, directions or relative sizes of objects. Yet on a clear day in Antarctica 'you can see for ever'. The air is so clear, so free of dust, that it is quite surprising how distant objects can be seen very clearly. On other occasions ice crystals in the air can produce a most complex array of optical effects.

In a blizzard the noise of the wind whistling around rocks, buildings or even a tent can be unusually shrill and loud. But when there is no wind out on the Antarctic plateau it is the silence that is surprising. There can be times when there is no noise whatsoever. If you think about it, that is a really unusual situation.

Read on to discover and understand other unusual Antarctic occurrences.

The study of science

Science began with the observation of natural events.

A visitor to a modern research laboratory would probably be most struck by the sophisticated instrumentation. You may think that science has gone beyond dealing with ordinary events and phenomena. Yet investigative science still begins with an observation that demands further study.

In Antarctica conditions are so unusual that it is a major challenge to relate observed events to the scientific principles formulated in familiar environments.

The examples that follow have been drawn from published accounts of Antarctic expeditions. People who have been to Antarctica can always relate unusual and interesting phenomena.

This is not merely a collection of facts. It offers an opportunity to test understanding of some of the principles of science. How can this observation be related to the principles we have learned? Can our knowledge of the universe be extended by investigating further some of the events that have been reported?

Heat flow

The air came down the chimney

In his book *The Crossing of Antarctica* Sir Vivian Fuchs writes as follows:

A curious event which often accompanied cold conditions at Shackleton was the reversal of the air flow in the radio room chimney. . . . a cataract of air would rush down, fanning the fire into life, and blue flames, smoke and sparks would belch from the lower part of the stove.

- Provide an explanation for the reversal of the air flow.
- What would you have done to re-start the air flow in the desired direction?
- The smoke and sparks were unpleasant, but there was a special danger as well. Suggest what the danger was.

Now read the complete statement (page 9) by Sir Vivian Fuchs and evaluate your answers.

Temperature profile of a polar tent

In another part of *The Crossing of Antarctica* Fuchs writes the following paragraph:

At the beginning of May, David Stratton began regular indoor climate observations which involved the use of numerous thermometers, thermographs and hydrographs at various levels from floor to roof, together with other periodic readings which entailed clambering about the rafters at all hours of the night and day. The results of these measurements revealed a remarkable temperature gradient. At foot level it would perhaps be just above freezing, at chest height 10°C , while in the apex of the roof 20°C or 26°C could be expected. Later on we used fans to give greater circulation, but even so the temperature at floor level remained lower than the

rest of the hut. The results of David's labours will be used principally by the Building Research Section of the Department of Scientific and Industrial Research, but they will also be of interest to the Medical Research Council.

- Can you suggest why this temperature gradient occurred?
- Where would you have placed the fans in order to improve circulation?
- In what way might the observations from this work be of interest to the Medical Research Council?
- Is there any suggestion for future action you would like to make to the Building Research Section?

A similar experiment was performed in a polar tent by a member of a New Zealand field party. At floor level the temperature was minus 10°C while in the apex 1.8 metres above it was 22°C . A primus stove was burning vigorously on the floor, but it failed to lift the floor temperature although the temperature at the apex increased to 30°C .

- Why was the primus ineffective in raising the floor temperature?

Melt water at seventy-nine degrees south

One exploration party approached Mt Faraway, which is at approximately 79°S latitude.

Read the following account of a part of their journey.

The weather was fine, with brilliant sunshine and temperatures in the plus 20s. In these conditions the snow became so soft that they were compelled to change to night travel, for then the cooler conditions provided a harder surface for the sledges.

Travelling fifteen to sixteen miles [24km-25.6km] daily, they reported their position to Shackleton every third day. Slowly Mt Faraway was joined by other

dark masses that came peeping above the horizon until a great rock wall intersected by steep glaciers could be seen extending out of sight to the east.

On 17 December they camped about 6.4km from Mt Faraway and next day found some difficulty in negotiating a wide stream of melt water rushing into a small lake that had formed on the surface of the ice some miles distant. Ultimately they found a way across and camped close to the rocks. Above were small waterfalls pouring off the precipitous rock and ice slopes to feed the river running along the foot of the mountains. It was surprising to find all this water in so high a latitude.

As the day advanced and the sun sank, it seemed that an invisible hand slowly shut off the supply of water, reducing the spouts and rushing torrents to mere trickles that gurgled their way beneath screes or dripped slowly from hanging masses of the tumbling ice falls. (Sir Vivian Fuchs)

- The temperatures were in the plus 20s on the Fahrenheit scale, still below freezing point. Can you explain why there was melt water present? (The answer appears on page 9.)

Keeping warm

By 9 May the temperature had fallen to minus 10°C accompanied by a 40mph [64km/h] wind which made outdoor work difficult and unpleasant. Next day the wind eased to 10mph [16km/h] but the temperature was below minus 60°F (minus 15.5°C).

At this time I took the Muskeg tractor to bring seal meat to the dog tunnels where it could be sawn up more comfortably in a temperature of minus 16°C. Driving was curiously difficult because of the clouds of condensed exhaust blowing ahead of the vehicle, making it impossible to see even a few yards. Jinking from side to side so as to get an occasional view ahead, I found that my knees were being burned by the cold air where the windproofs were stretched taut against them in the driving position. I then remembered that I was only using short underwear, but as soon as I stood up and moved about, the "burn" disappeared. (Sir Vivian Fuchs)

- Discuss the phrase "burned by cold air".
- Why did the 'burning' cease when the driver stood up and moved about? (For the explanation see page 9.)

- Use the experience described in this paragraph to explain why polar clothing is usually loose-fitting.
- Why are "fishnet" singlets often used in cold climates?
- Why are most outer garments used in the Antarctic fitted with draught-proof cuffs?

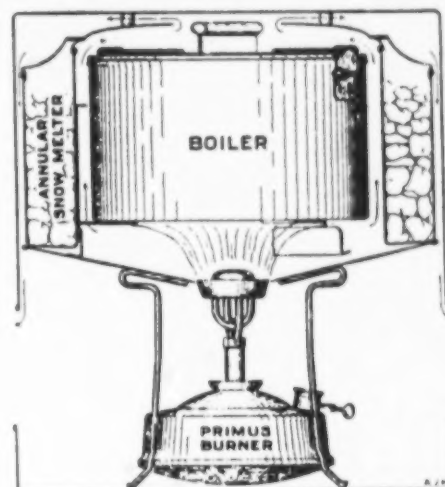


Figure 1
Section through a Nansen sledging cooker, mounted on a primus. (Illustration courtesy of Rigby Publishers)

The Nansen cooker

Carefully study the diagram of a Nansen cooker shown in Figure 1. Before they escape into the outer air the hot gases from the combustion of the kerosene vapour in the primus are made to travel along a circuitous path. Thus a hot meal is being prepared in the central vessel while the melting of snow for cocoa or tea is proceeding in the annulus.

- Trace the path of the hot gases.
- Why was this cooker such a useful device for Antarctic explorers?
- Which metal would you use to make the cooker? Give the reasons for your selection.

To melt or not to melt the ice

After their ship *Endurance* sank, Shackleton's party camped on the ice and the following occurred:

Shackleton ordered the men to shift camp because their floe was melting at a dangerous rate. The soot from the blubber stove had been tracked all over the surface of the ice. (Alfred Lansing)

Several times ships were frozen into the ice (beset) for the winter. There are records of men taking coal from the ship's bunkers and soot from the galley and distributing these materials on the ice around the ship.

- Why should coal or soot help to melt ice?
- Would you expect this procedure to melt sufficient ice to release a beset ship? Give reasons for your answer.

The large aeroplanes required to carry supplies to Antarctica presented a new problem. Snow was cleared from sea-ice and a 2000 metre runway laid out at McMurdo Sound. In summer the ice softened and holes developed. Many of the melt-holes had been started by a patch of oil or a piece of paper.

- How could oil or paper cause holes in the ice?

After the ice runway was repaired, Admiral Dufek said: "If a man so much as walks on that new strip with dirty shoes, or throws away litter, I'll have him court-martialled!"

- Why was cleanliness so important?

Not so hot!

An expedition member wrote:

Can you imagine how long you have to wait for a cup of hot soup after a day running with dogs, when you have to melt snow first?

- Why should it take so long?

Inland at 2000 metres on the plateau, boiled water doesn't seem so hot.

- Why should boiling water seem to be 'not so hot'?

Spilling kerosene or diesolene on your skin can be dangerous in Antarctica as it can cause frostbite.

- Why should this be so?

Improving mattress design

A field report contained the following paragraph:

The new yellow and green-covered mattresses let through cold when camping on snow or ice and during the last two seasons I have had to use in addition a close-cell foam mat. As I have had considerable problems with these mattresses absorbing water from

pressure melting of the underlying snow, they need a waterproof base. It would help were they covered in a dark material so that drying would be speeded up. (R H Findlay)

- Comment on the writer's phrase "let through cold".
- In what way did the closed-cell foam mat assist?
- In what way would the dark material speed up drying?

Explanations

The air came down the chimney (from *The Crossing of Antarctica* by Sir Vivian Fuchs)

A curious event which often accompanied cold conditions at Shackleton was the reversal of the air flow in the radio-room chimney. This would happen if the small coal stove was shut down too low for the night. The column of cold air that formed in the upper part of the chimney would gradually overcome the upward draught and suddenly a cataract of air would rush down, fanning the fire into life, and the blue flames, smoke and sparks would belch from the lower part of the stove. Soon the room would become thick with fumes which gradually spread to the rest of the hut.

At first we could not understand what had happened, but we soon discovered that the only cure was to cover the top of the chimney with a sack and use blow-lamps to heat the metal stove-pipe. When this was really hot, the sack would be snatched away and the contained hot air would re-start the right cycle of events.

Apart from the unpleasantness it was distinctly unhealthy to allow this back-draught to occur, for on the first occasion it happened we found that there was sufficient carbon monoxide in the radio-room to be dangerous to life in one hour. After that the night 'met' man kept a careful eye on the stove in cold weather.

Melt water at seventy-nine degrees south

Even at 79°S latitude, dark-coloured rocks absorbed enough heat to melt nearby snow.

Keeping warm

Human skin records a burning sensation whenever there is a rapid transfer of heat. In this case the body lost heat by conduction. The fact that the driver obtained relief by moving around illustrates the efficiency of the windproof principle—that a body of air retained next to the skin is the primary requirement for warmth.

Optical phenomena in Antarctica

The accounts of expeditions to Antarctica make many references to unusual optical phenomena. Explanations are rarely included, and the notes that follow are intended to provide a ready reference on those observations most frequently reported:

Water sky and ice blink

Mirages

The refracted sun

Haloes and mock suns

Whiteouts.

Water sky and ice blink

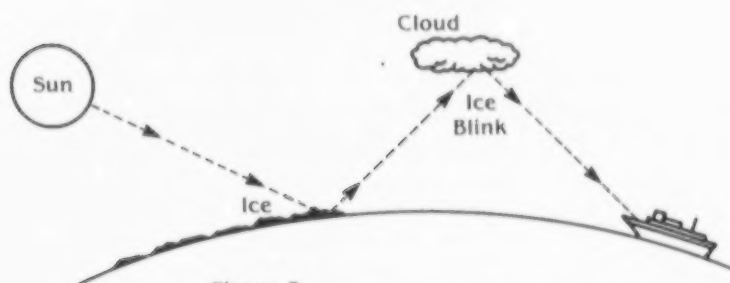


Figure 2
Ice blink is caused by reflection of the sun's light off ice onto cloud. (M.L. Yaxley)

As ships move through the pack ice, their crew members look hopefully for a black zone on the horizon. This is the water sky, which indicates that under it there is open, ice-free water. For ships beset in the ice, such as the *Belgica*, *Gauss*, *Discovery*, *Endurance*, a water sky held out hope of escape from the grip of the ice. From the shape and size of the dark streaks in the sky, experienced sailors can estimate the outline and size of the open water below.

The presence of the dark water sky indicates water is not so reflective as ice. A high proportion of the sun's radiation is absorbed by the water and its suspended plant life.

Ice blink (see Figure 2) represents the same phenomenon in reverse—it is the luminous appearance on the horizon of the sea caused by reflection from ice.

Mirages

In Antarctica it is not unusual to find that the temperature of the air near the surface increases with height. This type of temperature distribution is called a "temperature inversion". Such a condition may occur when the sea is much colder than the air above. The temperature of the layer of air in contact with water is low, but the temperature of successive layers of air rises very quickly as height increases above the sea.

The same thing is particularly prevalent above a frozen surface of snow or ice when it suddenly begins to thaw and the air close to the surface is colder than that higher up.

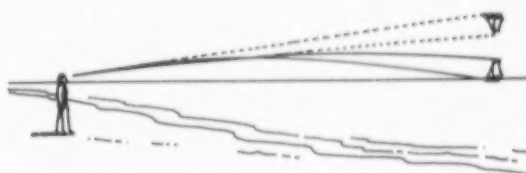
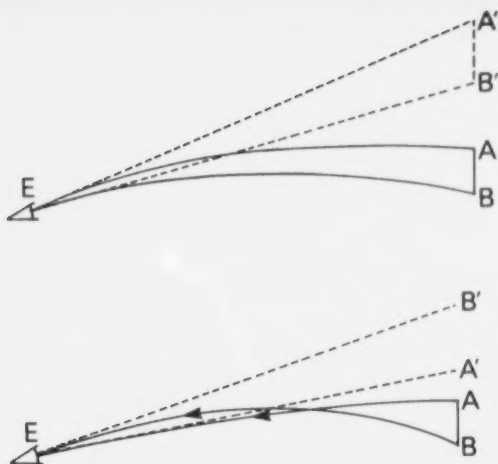


Figure 3
An inverted image above the horizon. (Illustration courtesy of Bell & Hyman Publishers)

Temperature inversions also occur at other heights above the surface and can give rise to mirages of either erect or inverted images (see Figures 3, 4 and 5). The double horizon is an example of an erect image. It was described as follows: "While driving across the ice shelf towards the Royal Society Mountains, one would see two piedmonts (foothill regions), one above the other, and above that the mountains would appear."

The images may be of geographic features that are, in fact, well over the horizon. This brought confusion to more than one of the early explorers of Antarctica. Sometimes they saw mirages without recognising them as such and marked their charts accordingly. Subsequent expedition members could not find the original features and controversy began. A greater knowledge of optics would have saved a few explorers' reputations.



Figures 4 and 5
Images caused by temperature inversions.
(Illustrations courtesy of Bell & Hyman
Publishers)

The refracted sun

Refraction is the deflection from a straight path undergone by a light ray in passing obliquely from one medium (such as air) into another of a different density (such as an ice crystal). Successive layers of the atmosphere can also act as different mediums.

In *The Crossing of Antarctica*, Sir Vivian Fuchs writes as follows:

On 23 April the sun finally left us and although some hours of twilight continued for many days we decided to postpone some of the seismic work until the return of the moon a fortnight later. We were therefore astonished when we went outside three days afterwards and found the whole base bathed in sunlight! This was due to refraction, but our newborn sun remained over the horizon for only 20 minutes, and the next day the same phenomenon again occurred.

Later on he writes of a similar occurrence:

Then on the fourteenth (of August) Peter Weston rushed into the hut calling out that the sun was back. Some, less disbelieving than others, ran outside into minus 13°C and a 32km wind, only to see a red glow on the northern horizon. Then a fraction of the sun's disc appeared again, flickered and disappeared. For some time it came and went, the greatest elevation revealing about one-tenth of the orb. Sometimes as it reappeared a red flash seemed to shoot out and pulsate along the horizon. This was an exciting moment, not only because the sun had come back to us, but because it had returned by refraction four days earlier than expected.

On both of these occasions the sun was below the horizon. The observers would not have seen the sun's disc had the rays travelled in straight lines. However, atmospheric conditions were such that the sun's rays were refracted and then reflected so that the sun's disc became visible (see Figure 6).

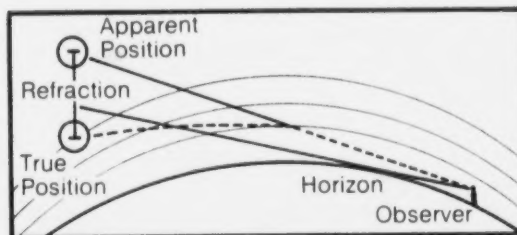


Figure 6
The sun's rays are refracted by successive atmospheric layers. (M.L. Yaxley)

Haloed and mock suns

Rings, or haloes, around the sun or moon are observed at all latitudes and have long been regarded as meaning bad weather. This is reasonable because there is a connection. Figure 7 outlines the observations that call for explanation.

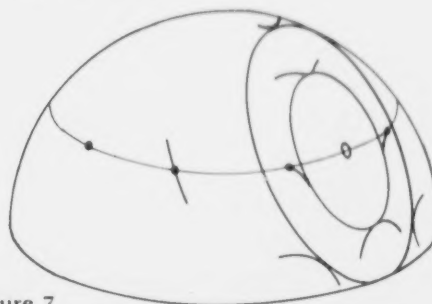
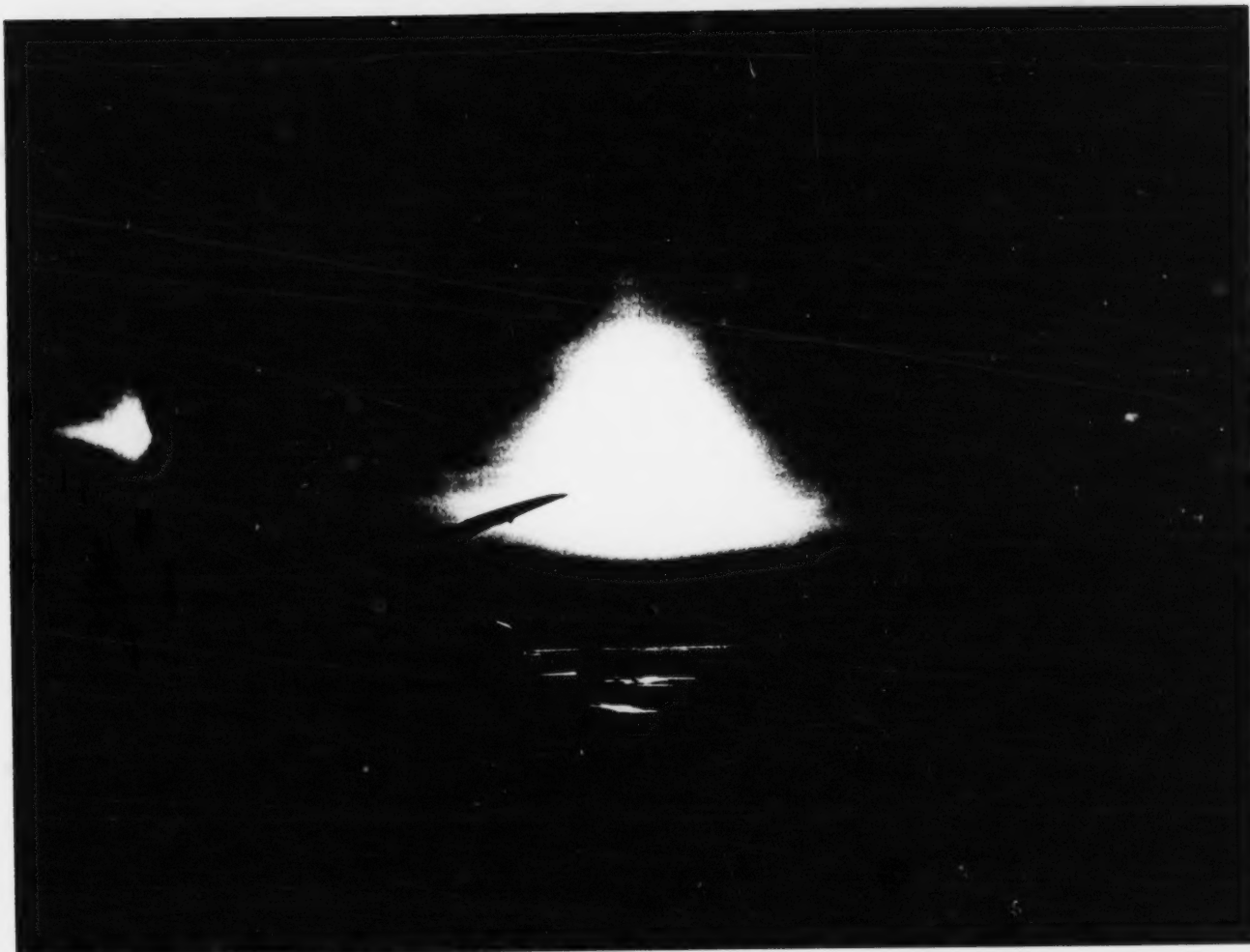


Figure 7
Typical arrangement of rings and haloes.
(Illustration courtesy of Bell & Hyman)

The sequence of events leading to halo conditions can be summarised as follows:

- a low-pressure system advances and the barometer reading drops;
- violent convection carries moist surface air up to altitudes where the temperature is below freezing point;
- the air becomes supersaturated with water vapour. (When the air holds more water vapour than it is normally able to take up at a given temperature, it is said to be 'super-saturated');
- ice crystals are formed by sublimation—that is, water vapour changes directly to a solid ice without



Mock suns, or sundogs. (Antarctic Division, Australia)

becoming liquid—and cirrus clouds result:

- high-velocity winds move the cirrus clouds ahead of and above the low-pressure system;
- the refraction and reflection of light, by crystals of ice in the air, produces the haloes and associated optical effects. The effects are most impressive when the clouds are thick enough to fill the air with crystals, but not so thick as to block out the sun.

In polar regions their variety of form and their splendour make atmospheric haloes objects of interest and admiration. During the first International Polar Year of 1882-83, haloes were systematically observed at a number of stations in the Arctic. In the Antarctic observations were made by several of the early expeditions, notably members of the *Belgica* in 1898-99 and the *Gauss* in 1901-03.

Forms of ice crystals

Ice crystallises in a hexagonal (six-sided) system. Hexagonal crystals possess four axes of which three lie in one plane and the fourth, the principal axis, is at right angles to the other three. The basic crystal form is shown in figure 8, with the principal axis vertical.

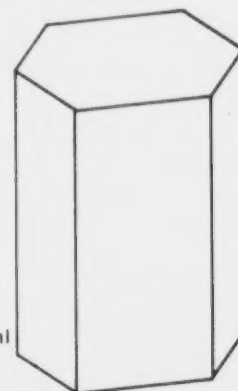


Figure 8 Basic hexagonal ice crystal.

The faces of the crystal can be developed to various extents, which gives rise to a great variety of shapes. The two most common

forms of ice crystals are plates and needles. In the case of the plate the principal axis is very short and the pyramidal plates are absent. This produces a flat disc, as in figure 9a. With the needle, the principal axis is long, giving rise to a narrow hexagonal prism (figure 9b).

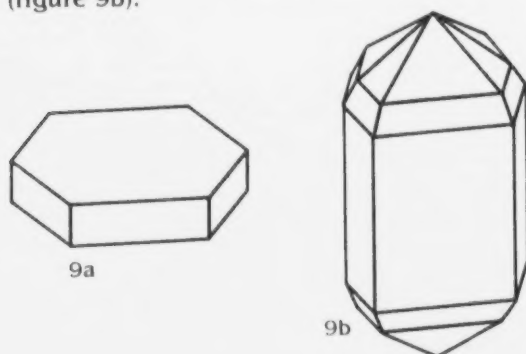


Figure 9a Plate crystal with short principal axis.

Figure 9b Needle crystal, with pyramidal plates.

Meteorologists—and glaciologists in particular—are interested in the halo effects because they provide some information about the nature of the ice crystals present in the atmosphere and the conditions in which they formed.

The hexagonal plates and needle-like columns, together with other crystals that have smooth, regular faces, share responsibility for the principal halo phenomena.

Two variations of the columnar crystals need to be mentioned. They are capped columns (figure 10) and "bullets", which are columns with one pyramidal end (figure 11).

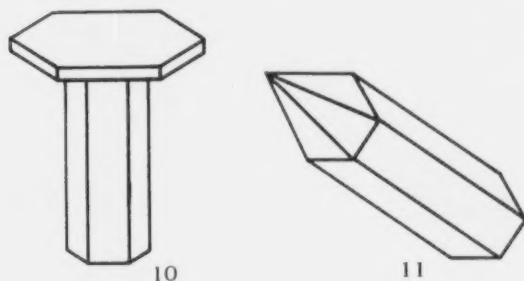


Figure 10 Capped columnar crystal.

Figure 11 Bullet crystal—a columnar crystal with one pyramidal end.
(Illustrations courtesy of *Scientific American*)

Two principal factors influence the type of crystal formed. They are the air temperature and the degree of saturation of the air with water.

The twenty-two degree halo

The halo seen most frequently surrounding the sun or the moon when they shine through large concentrations of ice crystals in the atmosphere is known as the 22° halo. It is so called because its radius "subtends" an angle of about 22° from the eyes of the observer. In other words, if the two ends of the halo's radius were joined by two lines to the observer's eye, the angle formed at that point would be 22°.

The halo is complete and clear as the crystals are evenly distributed in the atmosphere. It usually has bright spots at the top and bottom and to the far right and left. The inner edge of the halo is usually distinct, and red in colour; then follow yellow, green and white, changing to blue. Within the halo the sky is usually darker until the sun's corona is reached. Outside the halo the sky is usually brighter.

The 22° halo occurs when the light is refracted through the hexagonal ice crystals in such a way that the refracting angle is 60° (figure 12). The refractive index of ice is 1.31 for yellow light. (The refractive index is a measure of the power of refraction of a medium. It is the ratio of the rate of a light wave in a vacuum to its rate in the medium in question—in this case, ice.) If the path of the rays through the crystal is symmetrical, the deviation will have a minimum value, D , given by the standard formula

$$n = \frac{\sin \frac{1}{2}(A \pm D)}{\sin \frac{1}{2}A}$$

where n is the refractive index of ice and A is the refracting angle. For $A = 60^\circ$ and $n = 1.31$ we find that $D = 22^\circ$.

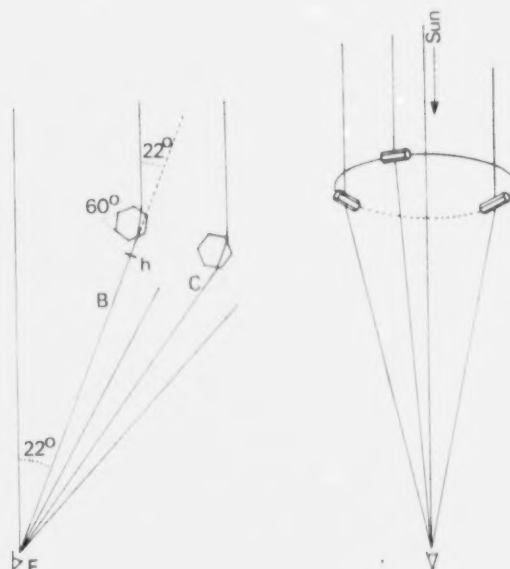


Figure 12
Sketch to show how the small or 22° halo arises.

The forty-six degree halo

The larger halo has the same colouring, but its brightness is less than that of the 22° halo. Consequently it is seen less often. It is produced in the same way, except that the rays are refracted through the ice crystal in such a way that the crystal's 90° angle acts as the refracting angle (figure 13).

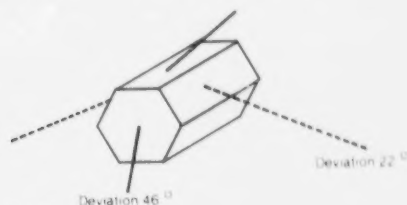


Figure 13
How the 46° halo occurs. (Illustrations courtesy of Bell & Hyman Publishers)

Mock suns

Frequently there are two concentrations of light on the small halo at the same altitude as the sun. These are called mock suns, parhelia, or sun dogs.

Sometimes only one of the two can be seen clearly or the halo itself is absent, leaving the clearly visible mock suns by themselves. The intensity of these mock suns

is striking. They are distinctly red on the inside, then yellow, changing into a bluish white. They are actually situated a little outside the 22° halo, the more so as the altitude of the sun is greater.

The mock suns arise when a large number of columnar ice crystals are oriented vertically, especially the umbrella-like capped columns. The light passes through alternate side faces of the columns, but since the faces are vertical and the sun is above the horizon, sunlight enters the crystal obliquely. The plane on which the light travels is not perpendicular to the principal axis. Thus a true minimum deviation does not occur, but a corresponding concentration of light appears outside the halo.

Halo variation

A very wide range of features is displayed in addition to the principal haloes already mentioned. They do not all occur simultaneously and physical explanations for some of them are lacking. The following two diagrams illustrate possible features of atmospheric haloes (figure 14) and a typical observed halo (figure 15).

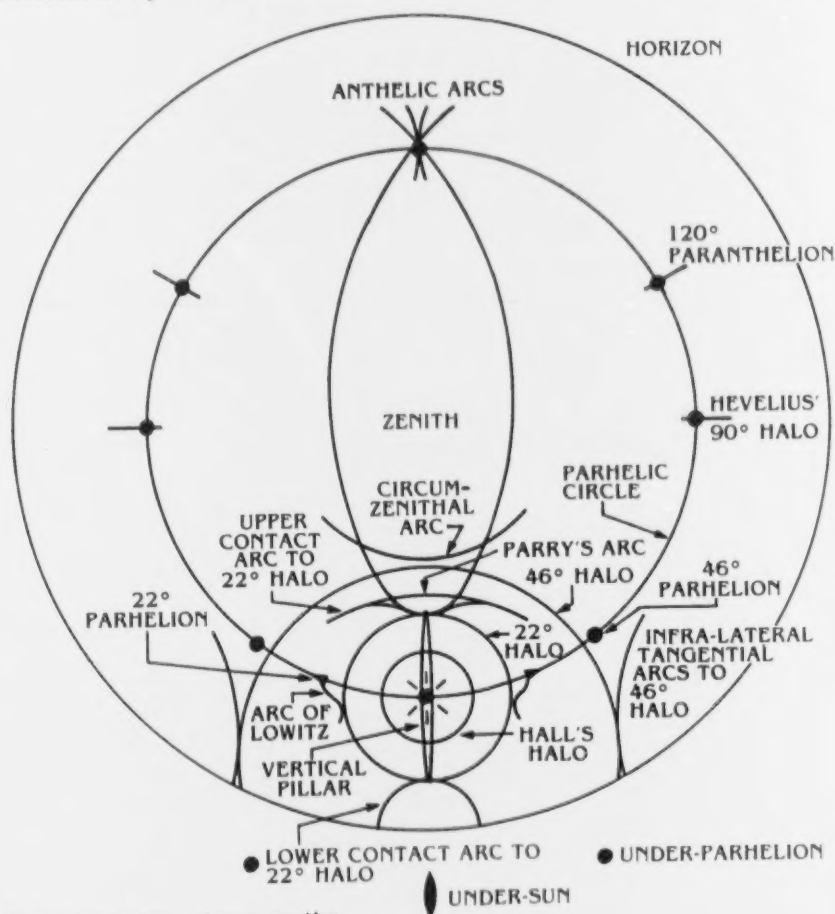


Figure 14
Some possible solar haloes, drawn on the celestial sphere. (Antarctic Division, Australia)

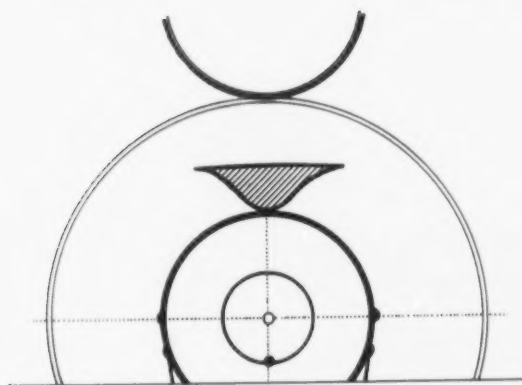


Figure 15
A typical observed halo. (Illustration after G.H. Liljequist, 1956)

During the Norwegian-British-Swedish Antarctic Expedition of 1949-52, systematic observations of haloes were made. Particular attention was given to a study of the ice-crystal forms that produced haloes at levels near the surface of the earth. However, haloes produced by ice crystals at both middle and high atmospheric levels were also studied.

Solar halo displays originating in low-altitude ice crystals over the ice-cap inland from Mawson were documented between 30 September 1958 and 17 January 1959. Haloes were recorded on thirty occasions on twenty days during the period 21 November 1958 to 5 January 1959, an interval of forty-six days. The halo form and the number of components change considerably during the single display, often becoming quite complex. Thus there is no shortage of information about the great variety of halo displays.

Simple plate crystals occur between 0°C and minus 5°C, then short columns down to about minus 10°C. Most of the optically interesting crystals develop when the temperature is in the range minus 5°C, to minus 26°C and the degree of saturation of the air is 110 to 140 per cent. When the saturation is higher than 140 per cent, the growth of the crystals is very rapid and their faces are not regular.

Composite crystals such as capped columns occur when a developing crystal descends through a stratified cloud where conditions vary in the different layers.

The orientation of the ice crystals as they fall through the air further influences the wide variety of optical effects that occur. When the crystals are exceedingly small, they are subject to random "Brownian motion" because of the impact of air molecules on them. (Brownian motion is the irregular oscillation of tiny particles, such as ice crystals, suspended in a fluid, such as air.)

Thus the crystals tumble constantly and there is no preferred orientation.

As the size of the crystals increases, air resistance becomes significant and the crystals become aligned with each other. This is the optimum condition for halo development.

Some of the effects, particularly arcs that pass through the sun or start there, are produced when light is reflected from the faces of descending crystals (figure 16).

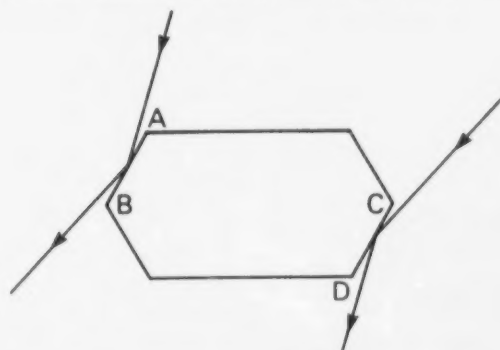


Figure 16 Some halo effects are produced when light is reflected from falling crystals.

A further possibility is that rays of light will enter a crystal and then be reflected internally (figures 17a, 17b). They, too, can produce characteristic arcs.

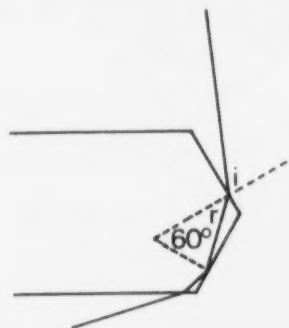


Figure 17a

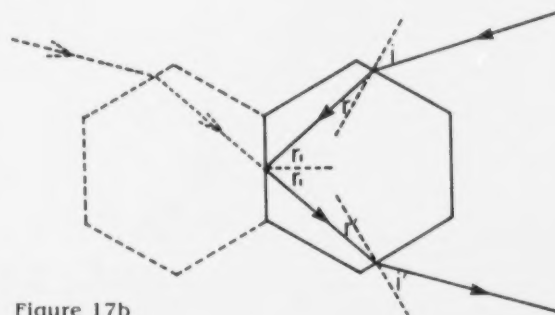


Figure 17b

Figure 17
Rays of light enter a crystal and are reflected internally, producing arc effects. (Illustrations courtesy of Bell & Hyman Publishers)

This is an area of study where not all the answers are known. Application of the principles of reflection and refraction of light have been found to explain those phenomena which have been tackled theoretically.



Figure 17c

Whiteouts

One of the greatest hazards for travellers in Antarctica is the whiteout, which affects fliers as well as people on the surface. It occurs when a thick cloud ceiling prevents the penetration of direct sunlight over white snow-and ice-covered terrain.

Light is reflected from snow to cloud and cloud to snow, back and forth in all directions until everything is diffusely lighted. There are no shadows, surface definition is lost and the horizon is obliterated.

In these circumstances, depth perception is lost so that one cannot judge distances and disorientation occurs. Sastrugi and crevasses become invisible. It often causes people to walk around disoriented without a reference point and they have a tendency to stumble or fall.

In a whiteout the loss of surface definition can be so complete that footprints in soft snow and toboggan tracks seem to disappear. People may walk into snowdrifts or walk off cliffs.

It is best to make camp and wait for good visibility when a whiteout occurs.

The problem for aviators is really severe because good visibility and fine flying weather may exist at one location while a short distance away there may be a complete whiteout. Without a horizon, a pilot is in trouble. In Antarctica there have been several serious accidents due to whiteout conditions. The description given here comes from *Survival in Antarctica*, a handbook published for expeditions by the U.S. National Science Foundation.

In 1955 an expedition aboard the icebreaker *Atka* surveyed the Ross Ice-Shelf from the Bay of Whales to Okuma Bay to select a site for Little America V. At Kainan Bay it was decided to make seismic measurements of Ross Ice-Shelf thickness to determine whether the shelf was grounded.

A helicopter was dispatched to assist the task. After deploying a scientist and his equipment, the helicopter crashed into the ice-sheet at full power and tumbled for about 70 metres before coming to a stop. Its pontoons were in the air and the machine was completely demolished. Another helicopter was sent from *Atka* to pick up the badly injured pilot.

As the second helicopter took off from the crash site, its pilot kept his eyes on the wreck below. Then he looked for the clearly defined horizon formed by the ice edge against a grey sky. Spotting the tip of *Atka's* mast five kilometres away, the pilot headed toward it at 55 knots when he felt a jolt. The helicopter had flown into the ice-shelf. But luck prevailed because the pontoons hit flat and bounced the machine back into the air. No damage was done to the helicopter and the injured pilot, who died three hours later, was delivered to *Atka*.

Problem

Consider the following scenario. Geologists have set up a base camp on the polar plateau near a rocky mountain outcrop in the Transantarctic Range. They will be out in the field examining rock structures and collecting specimens. There is always the possibility that a whiteout may occur while they are out in the field.

- What prior steps would you suggest they take in order that they will be able to return to their base camp in the event of a whiteout?

Windchill

The windchill factor

It is a common observation even in temperate climates that a person may feel colder on a windy day than on a calm—but colder—day. The term "windchill" is used to explain this. In plain terms, we are dealing with the rate at which the body is cooling.

At low temperatures, with a wind, body heat may be removed faster than the body can replace it. This is when frostbite occurs, because the heat loss is sufficient for body tissues to freeze. Thus lower air temperatures or higher wind velocities will increase the danger of frostbite. The combined effect of wind and temperature is expressed as an "equivalent temperature", which is the effective temperature acting on exposed flesh.

When the windchill index was being developed, a series of experiments was carried out to measure the rate at which a cylinder of water froze. The investigators measured accurately the exact length of time that the cylinder remained at freezing point while it was giving up its heat of crystallisation.

- Design a set of equipment to allow you to conduct a similar series of experiments.

When blowing snow contacts warm skin, some of the snow melts and the skin becomes moist. Wet skin loses heat at 24 times the rate of dry flesh, so answering a call of nature in a blizzard can be an agonising experience.

The windchill equivalent temperature chart

The windchill index chart can be used to determine the windchill equivalent temperature. It also shows the windchill factor by measuring the loss of heat from a heated body in terms of kilogram calories per square metre per hour. Thus with a temperature reading of minus 40°C and a wind of 3 km/h (less than 1m/sec) the windchill factor is 1400 kilogram calories per square metre per hour—a point at which exposed flesh freezes.

- Read the instructions under the windchill index chart.
- Discuss the problem of working outside when the temperature reading is minus 20°C at different wind speeds.
- Use the index chart to determine the equivalent temperature for readings of 5°C and 5 km/h.
- What additional variables would have an influence on the actual effective temperature in a specific instance?
- Outside Antarctica, are there any other people who might have special reasons for learning about windchill?

To obtain equivalent windchill temperature, select current temperature value (C°) at right side of curve; move horizontally to the left to a point vertically below the current wind velocity (km/h); follow to the left and downward to the nearest parallel line until you intersect the 5 km/h vertical line; go back horizontally to the right and read off the equivalent windchill temperature.

Example: at minus 18°C with a 32 km/h wind the equivalent windchill temperature would be minus 43°C.

Curves are based on Paul Siple's index as published in Quartermaster Research and Engineering Command, *USA Technical Report EP-82*, "Windchill in the Northern Hemisphere", Falkewaki and Hastings, February 1958.

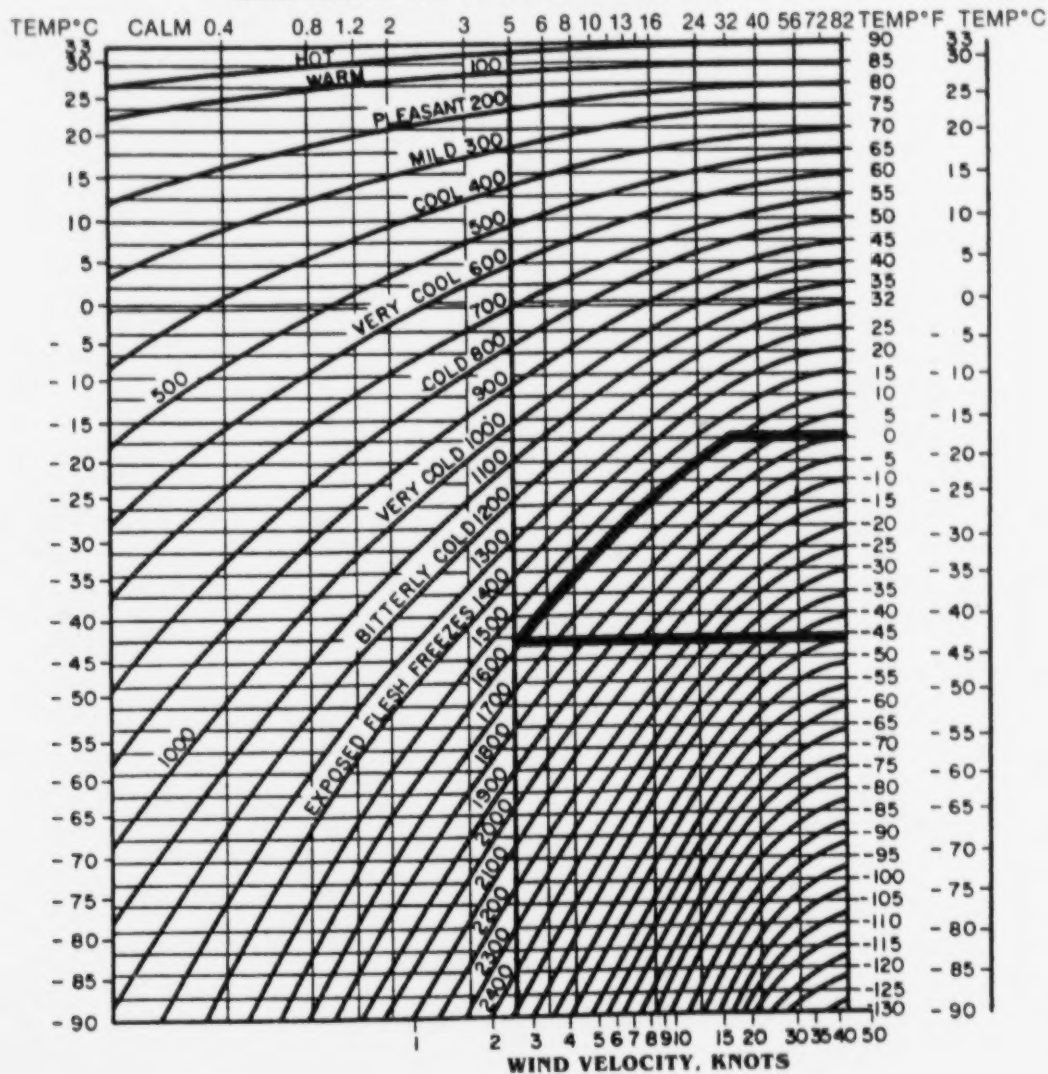
WINDCHILL EQUIVALENT TEMPERATURE

WIND VELOCITY (Km/hr)

°C	5	6	8	10	11	13	15	16	24	32	40	56	72	81	
25	25	24	24	23	23	23	23	23	22	22	21	21	21	21	LITTLE DANGER FOR PROPERLY CLOTHED PERSONS
20	20	19	19	18	18	17	17	16	15	14	14	14	13	13	
16	16	14	13	13	12	12	11	10	09	08	07	06	05	04	
13	13	12	11	09	09	08	08	07	05	03	02	01	01	00	
10	10	08	07	06	06	04	03	03	01	-01	-02	-04	-05	-06	
07	07	06	04	03	02	01	01	00	-03	-05	-07	-09	-09	-11	
04	04	03	01	00	-01	-02	-03	-05	-07	-09	-12	-14	-15	-16	
02	02	00	-02	-03	-04	-06	-07	-08	-11	-14	-16	-19	-20	-21	
-01	-01	-03	-04	-06	-08	-09	-11	-11	-16	-18	-21	-25	-26	-27	
-04	-04	-06	-08	-09	-11	-12	-14	-16	-20	-23	-27	-29	-31	-31	DANGER FROM FREEZING OF EXPOSED FLESH
-07	-07	-09	-11	-13	-14	-16	-19	-20	-25	-28	-31	-33	-36	-36	
-09	-09	-12	-15	-17	-18	-21	-22	-24	-29	-31	-36	-38	-39	-40	
-12	-12	-15	-18	-20	-22	-24	-26	-27	-33	-36	-39	-43	-44	-46	
-15	-15	-18	-21	-23	-26	-27	-29	-31	-36	-39	-43	-48	-49	-50	
-18	-18	-21	-25	-26	-28	-30	-32	-34	-40	-43	-47	-52	-53	-54	
-21	-21	-24	-27	-29	-32	-34	-36	-38	-44	-47	-52	-57	-58	-59	
-23	-23	-27	-31	-33	-35	-37	-39	-41	-47	-51	-56	-61	-62	-64	
-26	-26	-30	-33	-36	-39	-41	-43	-44	-51	-55	-61	-65	-67	-68	
-29	-29	-33	-36	-39	-42	-44	-46	-48	-55	-60	-65	-69	-72	-74	
-32	-32	-36	-40	-42	-44	-47	-50	-52	-59	-64	-69	-74	-76	-79	GREAT DANGER
-34	-34	-39	-43	-46	-48	-51	-53	-55	-63	-69	-73	-78	-81	-84	

WINDCHILL INDEX

WIND VELOCITY, KILOMETRES PER HOUR



To obtain equivalent windchill temperature, select current temperature value (C°) at right side of curve; move horizontally to the left to a point vertically below the current wind velocity (kmph); follow to the left and downward to the nearest parallel line until you intersect the 5 km per hour vertical line; go back horizontally to the right and read off the equivalent windchill temperature.
 Example: At -18°C with a 32 km/h wind the equivalent windchill temp. would be -43°C. (Table courtesy of Paul Siple and Putnam Publishing Group)

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Atmospheric pressure

Finding altitude without an aneroid

The diagram at Figure 18 shows a hypsometer, a double-walled copper vessel that used to be a familiar piece of equipment in school laboratories. It was used for determining the upper fixed point of an uncalibrated thermometer.

Water was steadily boiled in the lower part of the hypsometer, thus keeping the bulb surrounded by pure water vapour at atmospheric pressure.

Early Antarctic explorers took hypsometers with them. This was before suitably sturdy aneroid barometers were available.

- Explain how a hypsometer could be useful for determining elevation above sea level.
- Can you suggest why the vessel had a double wall?
- Can you give a reason for having a manometer on the side? Could the hypsometer be used without the manometer?

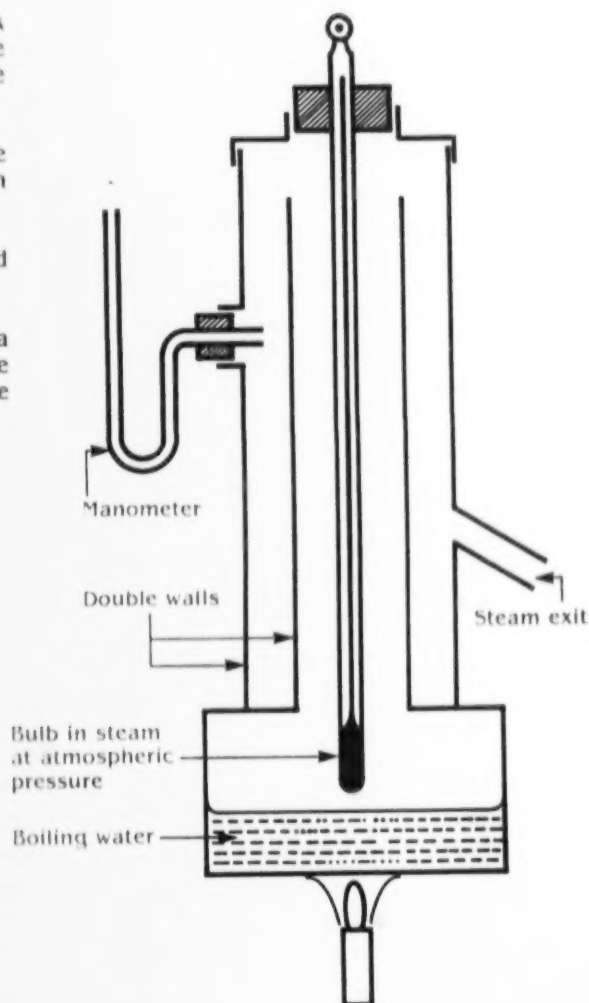


Figure 18
A Hypsometer.

Magnetism

The rebellious magnet

In Amundsen's account of his journey to the South Pole in 1911, he includes the following paragraph:

That day we had a curious experience, which was useful for the future. The compass on Hanssen's sledge, which had always been reliability itself, suddenly began to go wrong; at any rate, it did not agree with the observations of the sun, which we fortunately had that day. We altered our course in accordance with our bearings. In the evening, when we took our things into the tent, the housewife (a case for sewing articles), with scissors, pins, needles, etc., had lain close against the compass. No wonder it turned rebellious.

- Explain why the compass was "rebellious".
- What other precautions would the party have made to ensure the compass was not giving irregular readings?
- Would you expect that continuous low temperatures, say minus 40°C, would influence the operation of a magnetic compass?
- As the party approached the Geographic Pole, would the compass needle have pointed directly toward it?
- Draw a diagram to illustrate the following observation: "Because lines of magnetic force are very oblique to the earth's surface, compass needles are apt to jam."
- In the Ross Dependency compass navigation is difficult because one has to "go north to go to the South Pole". Can you explain this?

The South Magnetic Pole

Broadly speaking, the earth behaves as though it contained a bar magnet inclined at

a small angle to its axis of rotation and with its South Pole in the Northern Hemisphere (see Figure 19).

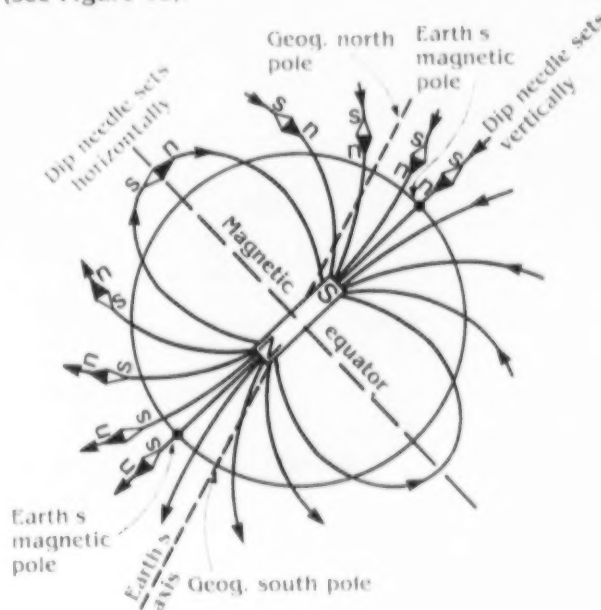


Figure 19
The imaginary magnet inside the Earth.

Observations show that:

- the Magnetic North and South Poles do not coincide with the Geographic North and South Poles;
- the magnetic poles are not fixed points, but drift appreciably from year to year;
- the earth's field is considerably more complex than a bar magnet and contains a number of irregularities.

When Sir Edgeworth David, Sir Douglas Mawson and Dr Mackay of Shackleton's 1907-09 expedition first located the magnetic pole in Victoria Land, it was at latitude 72°25'S and longitude 155°16'E.

In 1975 the pole was off the coast of Adelle Land at 65°48'S latitude and 139°18'E longitude. These two positions are about 1000 kilometres apart.

Using a magnetic compass in Antarctica is not a simple matter.

- Look at the sketch map at Figure 20. If David, Mawson and Mackay had wanted to set out for the South Geographic Pole after they had located the South Magnetic Pole, which compass direction would they have taken?

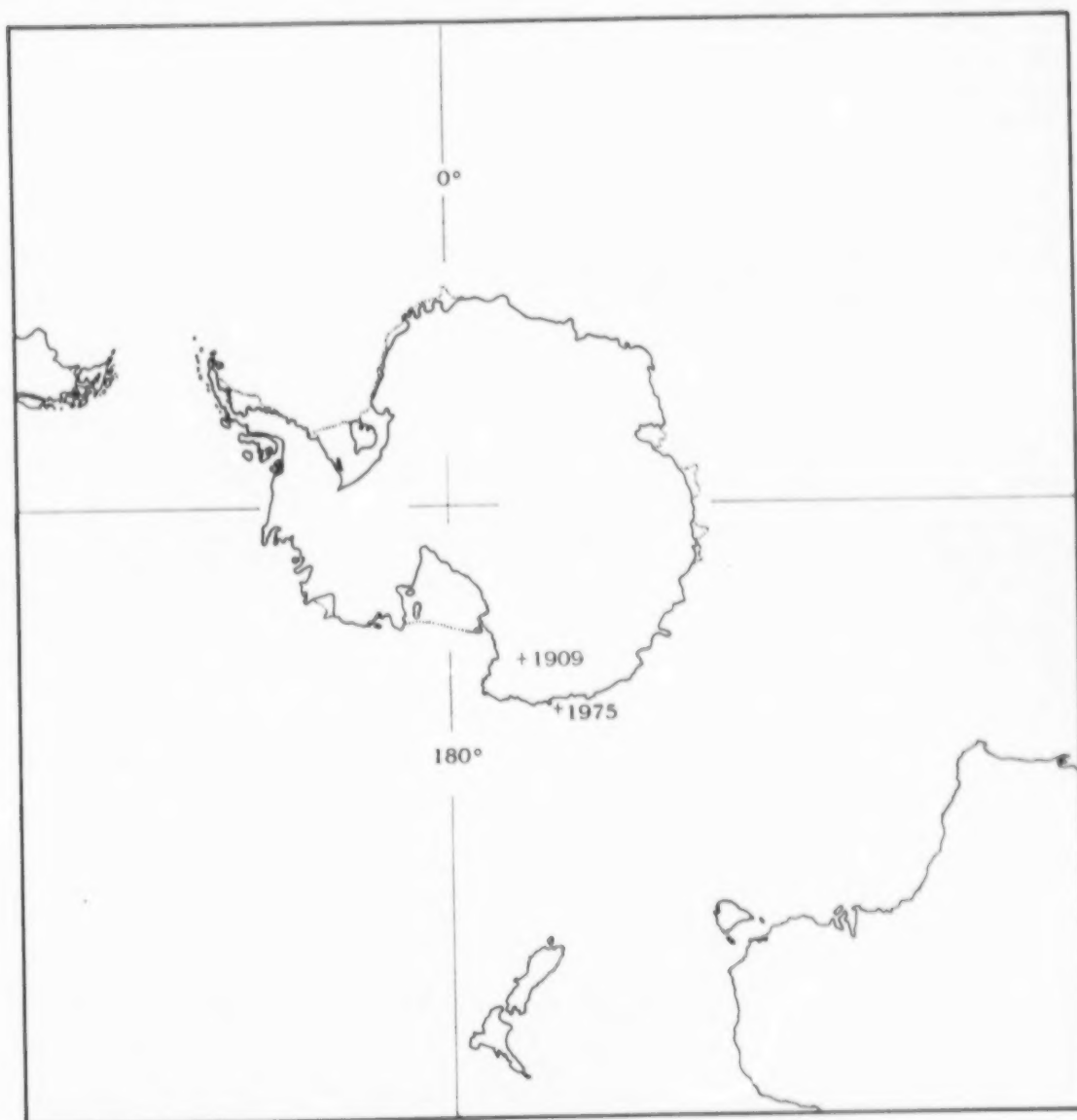


Figure 20
Movement of the magnetic pole. (M.L. Yaxley)

Electric charge

A shocking affair

A physicist who worked at Mawson wrote the following statement:

I recall the vicious electrostatic shocks that my leatherette and iron office chair used to produce. Of course, this effect of a dry atmosphere means that inflating hydrogen-filled balloons must be done with great care. (John Phillips)

- In what way did the chair most probably become charged?
- Why should the inflating of the balloons have been done with great care?
- What action would you have taken in the area where the balloons were inflated in order to minimise the risk?

Another Antarctic veteran wrote:

I seem to remember that metal-sheathed buildings, such as those with external skins of polished aluminium at Mawson and Davis, had a marked tendency to accumulate static electricity whenever blowing or drifting snow hammered the buildings . . . touch the metal with the tips of the fingers or an ungloved hand and the resultant shock would be more than a gentle tingle.

- Can you provide an explanation for the charging effect?

There also are reports of helicopters and their underslung loads becoming charged. For example, men have been thrown several metres because they tried to grab a load before it had been discharged by touching earth.

- What was the source of the charge in this case?
- Why are electric detonators not recommended for use during blasting operations in Antarctica?

Friction

Friction on sledge-runners

At Shackleton Base one of the scientists devised a series of experiments to investigate

... friction between different types of sledge-runner materials in varying temperatures and on different snow surfaces. At first he used small man-hauled sledges carrying a known load, the amount of effort required to 'break out' the sledge or to keep it in movement ... was measured ... (Sir Vivian Fuchs)

- Do you expect that friction would vary with temperature? Give a reason for your answer.
- Do you expect that the effort to "break out" the sledge would differ from the effort needed to keep it in movement? Why do you give this answer?
- How would you have measured the effort in each case?
- If you had been doing this experiment, which materials would you have tested as sledge-runners? Give reasons for your choice.
- It also was reported that the runners on some sledges were widened. What advantage would come from doing this?

Note that even low-friction sledge-runners melt the surface snow. The runners are then frozen in when the sledge stops. Hence they must be broken free before the sledge can move again.

Night marches on the ice

Another night march was commenced at 8pm. The day had been cloudless and the sun very warm ... (Sir Douglas Mawson)

- What were the advantages of travelling with dogs and sledges at night?

There were disadvantages (to night travel). The skirt of the tent used to get very wet through the snow thawing on it in the midday sun ... the floor-cloths and sleeping bags also never had a chance of drying ... (Sir Douglas Mawson)

- What do you think happened to this equipment when it was packed up for night travel?

Icy slopes

An excerpt from a field report reads as follows:

Traction on ice slopes was difficult, it was greatly improved when there was light snow cover on the ice. It was also increased when we rode 'two-up' on the toboggans. (RH Findlay)

- Offer an explanation for these observations.

Travelling over crevasses

The trackload of a Sno-Tric toboggan is about two thousand newtons per square metre.

- Determine a corresponding figure for the pressure exerted by a man who tips the scales at one thousand newtons when fully clothed.
- Now write a few sentences of advice to anyone who might have to travel across an area where there are bridged crevasses.

Chemical reactions

A pocket full of dynamite

When he was setting up his base at Cape Denison, Mawson wrote the following report:

Among other things it was found difficult to fire the charge, for, when frozen, dynamite is not readily exploded. This was overcome by carrying the sticks inside one's pocket until the last moment.

- Can you offer a reason why the frozen dynamite did not readily explode?
- Why should it help to keep the dynamite in your pocket?

Carbon monoxide poisoning

Carbon monoxide poisoning, especially of field parties using either kerosene primuses or butane gas stoves, is a serious problem in Antarctica. Carbon monoxide (CO) is a product of incomplete combustion. Discussion of the following questions may lead to a better understanding of the problem.

- What factors prevent complete combustion?
- What level of CO in the air is dangerous?
- What is the effect of CO on the human body and what are the symptoms?
- What treatment is appropriate?
- To what extent can good ventilation prevent CO poisoning?
- Does the use of bottled gas eliminate the danger of carbon monoxide poisoning or does it present different problems?

Incomplete combustion can result from:

- the use of watery or dirty kerosene;

- condensation from the outside of a pot of snow dropping on to the flame;
- accumulated soot or spilt food on the burner;
- a large, cold utensil being so close to the primus flame that the temperature of the flame is reduced.

The maximum allowable concentration of CO in the air which can be inhaled and no effects felt after eight hours is only 50ppm or 0.005 per cent. A concentration of 0.4 per cent can be fatal after one hour.

Carbon monoxide affects the body chemistry in several ways. It combines reversibly with haemoglobin to form carboxyhaemoglobin and this reduces the amount of haemoglobin that is available for carrying oxygen.

The presence of the CO also increases the affinity of the haemoglobin for oxygen, which means that the oxyhaemoglobin in the blood releases its oxygen to the tissues less readily. The higher nerve centres are also affected.

The symptoms of CO poisoning may not always be apparent, but they include headache, dizziness, nausea, dimming of vision, impairment of judgement, less co-ordination of muscular movements and increased pulse rates. Obstructive, unco-operative behaviour has also been observed among victims of CO poisoning. Mild difficulty with breathing and increased heart activity (such as throbbing) will accompany physical exertion. Unconsciousness comes later.

One expedition member reported that unconsciousness may occur before any other symptoms are evident. The effort of getting out of the tent may be enough to cause a person to lapse into unconsciousness if he or she has been exposed to increasingly high levels of carbon monoxide for some time.

Treatment is based on getting fresh oxygen into the blood and on removing the CO from the blood. Therefore the patient has to be removed to fresh air. If pure oxygen is not available, the patient must be encouraged to breathe deeply so his or her blood will be ventilated more quickly. If the patient is unconscious, mouth-to-mouth

respiration should be given. About 15 per cent of the CO in the blood is eliminated each hour at rest. Thus the half-life of the CO in the blood is about four hours.

Ventilation

It is useful to consider the amount of fresh air required to cook a meal. It has been suggested that in Antarctic conditions it takes one and a half hours to prepare a meal using a primus. During this time about half a kilogram of kerosene would be used. This requires more than seven and a half cubic metres of fresh air. When one considers that the volume of the typical polar tent is approximately 3.4 cubic metres, one can see that the air must be completely exchanged in this period. Good ventilation is certainly essential. On the odd occasions when there is no wind this becomes a real problem.

Even when there is a lot of wind, good ventilation is not a foregone conclusion. Closely woven material from which modern tents are made does not ventilate very well. Therefore most ventilation is through tube ventilators near the tent apex. These tubes can partly, or even completely, freeze over, so they have to be inspected periodically.

Gas expands as it leaves a bottle or

cylinder. It takes heat from the air and the bottle in doing so. This further impairs the efficiency of the combustion and at temperatures below minus 10°C efficiency may be so poor that unacceptable amounts of carbon monoxide are produced.

There is the additional problem that bottled gas is much more bulky to transport. Its volume per unit of heat is higher than for liquid fuels.

Melting ice can be dangerous

A member of a field party reported as follows:

- When placing a large pot of ice-blocks, to be melted for water, on the primus, one found that the bottom of the pot became wet as the water from the combustion of the fuel in the flame condensed on the cold mass of the pot. The danger from this was incomplete combustion and carbon monoxide poisoning. (R H Findlay)
- What procedures would you recommend in order to minimise the dangers referred to above? (see Figure 21).

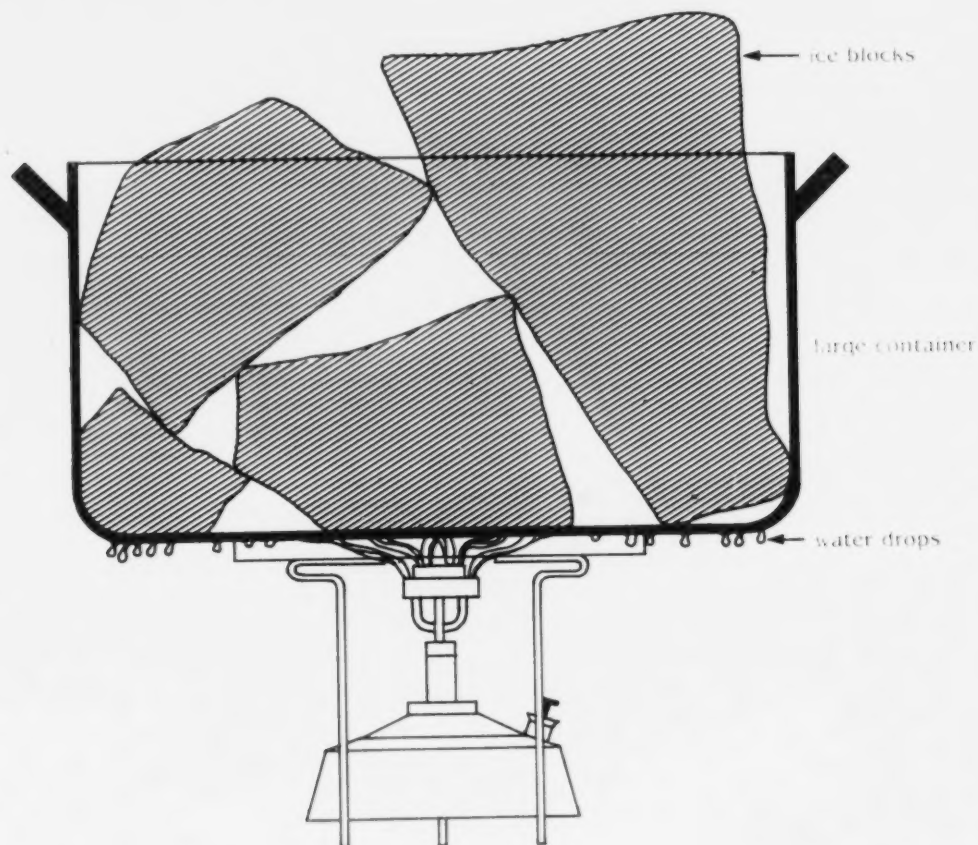


Figure 21
Melting ice can be dangerous. (M.L. Yaxley)

Making concrete in Antarctica

Stated very simply, concrete is made by mixing rock aggregate, cement and water and allowing them to set slowly. It is obvious that people will encounter problems if they have to make concrete at near-zero or sub-zero temperatures. If the water freezes before the normal chemical reactions that take place in concrete have a chance to occur, the concrete may well break up in the following summer.

- Make a list of steps you could take to ensure a concrete mix prepared in sub-zero conditions cured properly. Then read the following report by G E Varcoe of the Antarctic Division, New Zealand. Discuss the scientific principles related to the steps taken in the test that he describes.

Site preparation

The site for pouring was levelled and covered with a 10cm-thick layer of reasonably fine aggregate, in order to insulate the slab from the underlying permafrost (subsoil which stays frozen throughout the year).

Mixing

Initially, water for the mix was heated to no greater temperature than 30°C, in order to avoid a "flash" set. However, as this moderately warm mix was difficult to work, water temperature was raised to 80°C and greater fluidity was obtained.

An air entrainer (12cc per 12 shovels of mix) and an accelerant (300cc per 12 shovels of mix) were used to assist workability and prevent premature freezing.

Placement

The low ambient temperature demanded rapid working following placement by usual methods. More than the normal amount of air bubbles developed, presumably as a result of using air-entrainer additive. The bubbles caused formation of a "bony" surface which had to be floated off rapidly before the concrete set.

The first slab poured proved too large (4m x 4m) to be worked up adequately before the concrete became unworkable. Later slabs poured were smaller (4m x 2m) and proved readily manageable.

Curing

Initially the slab was covered with black polythene and two electric fan heaters

were used to dry the concrete slowly to avoid cracking. As little curing had occurred after several hours, despite a core temperature of 6°C and near-envelope temperature of 1°C, the fan heaters were replaced by a Herman Nelson heater (15,000 BTU). After eight hours, the initial set had occurred and four hours later the surface set was complete. During this time, core temperature was about 12°C and envelope temperatures were approximately 15°C. This core temperature was maintained later, after removal of the Herman Nelson heater, by chemical reactions within the concrete. The solar heat on the black surface of the polythene sheet also assisted the curing.

All subsequent pours were heated in the same manner and despite maintenance of an envelope temperature of 15°C, no cracking occurred. No water or damp scrim (fabric, such as hessian) was required to maintain a damp surface.

Air entrainer

A chemical additive called an air entrainer is used to make the concrete mix flow more easily. The agent is usually a saponified (or soapy) resin that reduces surface tension.

Concrete normally has residual air linked by a capillary system to the external surface. This is most likely to happen if excess mixing water is used. The air entrainer subdivides the naturally entrapped air into minute disconnected bubbles—500 billion to 800 billion tiny bubbles per cubic metre of concrete. Thus water from outside cannot get into the concrete readily and it is not subject to freeze and thaw action.

Accelerants

Another additive called an accelerant is used to generate heat just after the mix is made. This prevents the mix from cooling prematurely and speeds up the usual exothermic reactions—reactions which produce heat—involving the cement becoming self-sustaining.

A range of inorganic salts can be used—aluminium chloride, calcium chloride, sodium chloride, sodium sulphate, sodium carbonate, etc. Because it is comparatively inexpensive, calcium chloride is used more often than the others.

Moving ice

Glacial noises

Douglas Mawson trudged toward the hut. He was alone and he knew that there was no life for many kilometres—no birds, no dogs, no people. Yet he later wrote the following account of observations made on 14 January:

About 11pm as the sun skimmed behind the ice slopes to the south, I was startled by loud reports like heavy gun shots. They commenced up the valley to the south and trailed away down the southern side of the glacier towards the sea. The fusillade of shots rang out without interruption for about half an hour, then all was silent. It was hard to believe it was not caused by some human agency, but I learnt that it was due to the cracking of the glacier ice.

- How would you explain these noises?

Avalanches to order

Early brochures describing a tourist cruise to the Antarctic Peninsula promised that avalanches from mountainsides would be seen. They went so far as to say the captain would blow the ship's whistle and an avalanche would occur.

Later brochures omitted this feature, as nature did not always co-operate with the captain. Furthermore, when an avalanche occurred naturally, very few people observed the event. They simply heard a rumble and saw a cloud of snow rising from the lower slopes.

- Do you think that the ship's whistle could cause an avalanche?

- Can you give an explanation for the fact that so few people actually witnessed an avalanche?

Note that because of the low humidity, avalanches are not very common in Antarctica. Slopes that would be impossible to traverse in temperate latitudes because of avalanche danger prove quite safe in Antarctica.

It Happened in Antarctica is one of a series of sourcebooks which are part of the Pacific Circle Consortium's Antarctic Project. There are four storybooks:

The Adventures of Salik the Husky (8-10 years)
The story of a Greenland husky pup's voyage to Antarctica, and how he learns to be a sledge dog.

Rocky the Rockhopper Penguin (8-10 years)
The tale of a brave and inquisitive rockhopper, and the voyage from his Macquarie Island home, across the Southern Ocean to Antarctica.

Oscar (10-12 years)
This true story tells of a husky named Oscar and his fight to remain "king dog" of the sledge team. He spends some time at the Melbourne Zoo and returns to spend his last days in the ice and snow.

Castles of Ice (11-13 years)
A true story of Antarctic adventure, "Castles of Ice" describes a sledging trip to the Douglas Islands and the difficulties and rewards of working in Antarctica.

Other sourcebooks in the series are:

Living and Working in Antarctica (11-14 years)
Why do people brave the ice and snow to work in the harsh Antarctic environment? Here are some of the answers.

Penguins (10-12 years)
Background information on penguins and case studies of three penguins—the Adelie, the emperor and the rockhopper.

Antarctica's Secrets Revealed (10-17 years)
This is in question-and-answer format, and provides a wealth of information about the Antarctic continent.

Antarctica: Discovery and Exploration (10-17 years)
A look at Antarctica from the first sightings and the expeditions of the heroic era through to present day research.

Campbell Island (11-15 years)
Campbell Island comes under New Zealand administration and is a meteorological base. The animals and plants are described and the effects of human interference are examined.

Macquarie Island (11-15 years)
This Australian sub-Antarctic island is introduced with information on its animals and plants as well as on human activities.

Oceanic Birds of Antarctica (11-14 years)
Case studies of three Antarctic birds—the south polar skua, the snow petrel and the Adelie penguin.

Learning Outcomes and Activities which can be used with these modules are included in the teachers' guide, *Teaching and Learning about Antarctica*.

For older readers:

The Polar Continent
Seals and Whales of the Southern Ocean
Whales of the Southern Ocean
Antarctic Foodchains
The Scientist at Work
From Snow to Icebergs
International Relations in Antarctica

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